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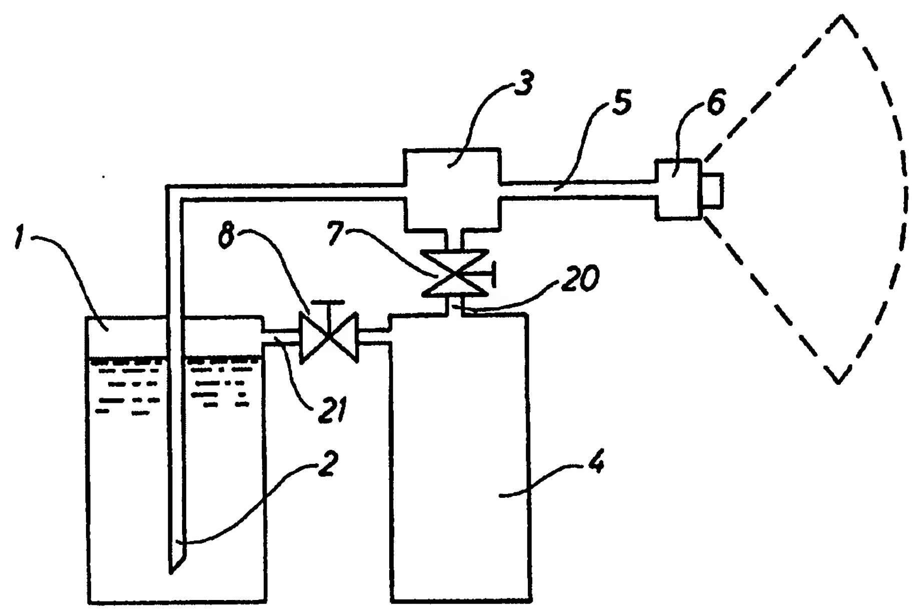
(54) Title: METHOD AND NOZZLE FOR PROVIDING A FLOW WITH SEPARATED GAS AND LIQUID PORTIONS SUBJECTED TO AN ACOUSTIC FIELD



(57) Abstract

A method of providing a gas/liquid jet having finely atomised liquid droplets comprising the steps of feeding a mixture of gas and liquid into a tube (5) provided with at least one outlet nozzle (6) having an outlet opening. A plug flow (i.e. a flow in which liquid portions and gas portions are separate from each other) is formed in the tube (5) before the flow leaves the nozzle (6). The outflowing plug flow is subjected to an acoustic field, the frequency of the plug flow thereof essentially being a multiple of the frequency of the plug flow and preferably close to the frequency thereof.

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Title: **Method and nozzle for providing a flow with separated gas and liquid portions subjected to an acoustic field.**

Technical Field

The present invention relates to a method and a nozzle for providing a gas/liquid jet having finely atomised liquid droplets and is especially but not exclusively directed towards the field of fire-fighting and can be used in relation to both portable fire extinguishers and stationary fire-fighting systems.

Background Art

It is known from "Physical and Chemical bases of the development and extinguishing of fires", 1980, pp. 182-187 by E.M. Abduraimov and Yu. V. Govorov that the efficiency of fire-fighting increases essentially in comparison with the use of solid jets of fire-fighting liquid or jets with large droplets when feeding finely atomized fire extinguishing liquid to the fire centre. The increase in fire-fighting efficiency is due to the heat exchange processes between the small liquid droplets and the fire centre being intensified. This results in a temperature decrease in the fire centre to the temperature of flame extinction and in decreased consumption of fire extinguishing liquid.

Thus, to increase the fire-fighting efficiency it is necessary to provide sufficiently high degree of liquid atomization.

Various methods of atomising fire extinguishing liquid are known as well as apparatus for carrying out said methods. One of the most efficient methods of atomising liquid is feeding of a gas/liquid mixture (in the following called GLM) through a spray nozzle as disclosed in USSR Inventor's Certificate No. 1353444, published in the Bulletin of the Inventions No. 43, 1987. In this case, under equal pressure, the GLM leaves the nozzle at a higher speed than a pure liquid flow.

It is known from "Atomizers of liquids. - M., Chemistry, 1979, by D.G. Pazhi and V.S. Galustov that an increase of the speed of the liquid outflow improves the atomization thereof. The method of liquid atomization used in the fire extinguisher is a typical example thereof as disclosed by USSR Inventor's Certificate No. 1225585, published in the Bulletin of the Inventions No. 15, 1986. Due to the high gas/liquid ratio and the high gas pressure, a higher speed of liquid outflow is provided.

USSR Inventor's Certificate N. 1316713, published in the Bulletin of the Inventions No. 22, 1987 - Method's Prototype, discloses that an even higher degree of atomization may be achieved by superposing acoustic vibrations on the outflowing GLM. Two flows are provided in this device, viz. the GLM flow and the gas flow. The gas flowing out of the Laval nozzle is directed to a specially installed Hartman generator which generates a powerful ultrasonic field. This field acts on the outflowing GLM providing a secondary disintegration of liquid droplets.

However, such a device is complex in construction and requires separate feeding of fluid and liquid.

The method of fire-fighting by a GLM according to USSR Inventor's Certificate No. 1316713, published in the Bulletin of the Inventions No. 22, 1987 - Method's Prototype, is considered the closest prior art of the method according to the present invention.

One of the basic elements of any fire-fighting means is the nozzle and the quality of atomization of any fire extinguishing liquid including a GLM depends on the construction thereof.

USSR Inventor's Certificate No. 1553151, published in the Bulletin of the Inventions No. 12, 1990, discloses a device by means of which a gas-liquid, mist-like spray is formed from a GLM. The device comprises a housing having a water

inlet and an air inlet, a movable rod spring-loading a deflector arranged on an end thereof adjacent an outlet and blocking the outlet, as well as a mixing chamber communicating with the outlet and with the water and air inlet. The mixing chamber communicates with the water through a ring chamber with the outlet ports to the mixing chamber, said ports being blocked by means of conical valve members rigidly connected with the rod and having spiral grooves on their surface. The air inlet communicates with the mixing chamber through a central channel and radial holes in the rod. Liquid from the ring chamber flows as separate jets to the mixing chamber. Also, transversely directed, compressed gas jets enter the mixing chamber and GLM is formed in the chamber. Under the influence of the pressure in the mixing chamber, the deflector plate of the rod is displaced from the opening, and the GLM sprayed out in a mist-like state.

USSR Inventor's Certificate No. 1426643, published in the Bulletin of the Inventions No. 36, 1988, Apparatus prototype, which is considered the closest prior art to the nozzle of the present invention discloses a gas/liquid nozzle comprising a chamber of changing sections into which a GLM is introduced. Liquid and gas passed separately to a first chamber part through a gas and an air inlet and mixed in said first chamber part. From the first chamber part, the GLM is passed into a cone-shaped chamber part and subsequently into a hemisphere chamber part provided with outlet openings for allowing the mixture to flow into the atmosphere. As the GLM leaves through the holes, a blow-like expansion of the compressed air takes place breaking the liquid film into mist-like droplets.

The described nozzle is mechanically complicated as to the formation of the mixture of liquid and gas.

Disclosure of the Invention

The object of the present invention is to provide a highly efficient method of providing an atomised spray with very fine droplets using GLM, said method

being particularly efficient in fire-fighting.

According to the invention, this object is obtained by a method of providing a gas/liquid jet having finely atomised liquid droplets comprising the steps of feeding a mixture of gas and liquid into a tube provided with at least one outlet nozzle having an outlet opening and being characterised by the features of the characterising part of claim 1.

In order to understand the principles of the method according to the invention, various GLM flows through a pipe-line provided with a nozzle are considered.

In case of small amounts of gas, i.e. when its mass concentration in the GLM does not exceed 0,4 weight %, a so-called bubble mode of gas/liquid flow is formed, i.e. gas bubbles (G) are more or less equally distributed in the liquid flow (L), confer Fig. 1. In this case, a stationary (without pulsation) GLM outflow is observed.

In case of very high amounts of gas in the order of 6 weight %, a pseudo emulsion mode is obtained, where liquid droplets (L) are more or less equally distributed in the gas flow (G), confer Fig. 2. In this case a stationary GLM outflow is also observed.

Finally, an intermediate mode, a so-called portion or plug mode of the mixture flow, is formed, confer Fig. 3, at certain GLM concentrations, in particular when the volume of gas and liquid is close to each other and at certain GLM flow modes (speed, pressure, pipe-line diameter). In this case, separate flows of liquid and gas portions along the pipe-line are provided, said portions being formed by the liquid surface tension forces causing single liquid droplets to merge, confer USSR Inventor's Certificate No. 1184567, published in the Bulletin of the Inventions No. 38, 1985.

When utilizing such a mode, the GLM outflow of the nozzle has a pulsating character due to the essential differences in the liquid and gas densities. The frequency of such a pulsation depends on the l-value and outflow V, confer Fig. 3.

In the method according to the invention, such a GLM flow is formed and flows out of the nozzle.

Further, on flowing out of the nozzle the GLM plug flow is subjected to an acoustic filed providing a resonance phenomenon. For this purpose, a frequency of the generated acoustic field close to the pulsation frequency of the outflowing GLM plug flow or being a multiple thereof is chosen. Thereby, the gas portions influence on liquid portions abruptly increase resulting in a more efficient dispersion or atomization of the liquid.

As mentioned above, the formation of a plug flow can be made in various ways, for example by selecting an appropriate gas concentration in the GLM. Formation of the acoustic field under resonance conditions with the pulsing GLM flowing out may be provided by means of the nozzle according to the invention or may be provided by other means, e.g. by an acoustic field formed by a separate source, such as an acoustic-electric transducer or a Hartman generator as described in USSR Inventor's Certificate No. 1316713.

The nozzle according to the invention comprising a housing forming a cavity and having an inlet opening and at least two outlet openings is characterised by the characterising features of claim 3.

Advantageous embodiments of the nozzle according to the invention are disclosed in claims 4 to 6.

Nozzles of similar basic constructions are known, (confer p. 90 of "Atomizers of

liquids. - M., Chemistry, 1979, by D.G. Pazhi and V.S. Galustov), but they have only been used for atomising liquids and not for GLM. The nozzle according to the invention is intended for atomising a GLM in the plug mode. A very high degree of atomization of gas/liquid flow is provided due to a resonance cavity or chamber being formed between the bottom wall of the small cylinder and a radial plane through the outlet hole(s) in said small cylinder. This provides the following mechanism of droplet disintegration, when the GLM flows out of the outlet holes. On the one hand, droplets disintegrate due to their collision (like jets collisions) and on the other hand liquid droplets additionally disintegrate under the influence of the oscillation of the GLM gas component taking place in the closed resonance cavity formed between the end wall of the small cylinder and a radial plane through the outlet hole(s) in said small cylinder.

The principle of the nozzle according to the invention is as follows:

- A GLM plug flow is formed;
- The flow is divided into two flows;
- One flow is passed through a first nozzle outlet hole;
- The second flow is directed to a resonance chamber prior to leaving the nozzle through a second nozzle outlet hole;
- In the resonance chamber, the GLM gas component energy is converted into the energy of acoustic radiation (acoustic energy);
- The generated acoustic radiation acts on the GLM flow and breaks the liquid droplets.

As the pulsation frequency of the outflowing GLM plug flow and the frequency of the acoustic radiation obtained by means of the energy from the gas component of the GLM flow equals one another, an effective breaking of the liquid droplets is obtained.

In the known acoustic nozzles, acoustic waves increasing the frequency of the

surface oscillations of the liquid disintegrate the liquid jets and improve the atomization. Consequently, the acoustic waves are provided in a gas medium separated from the GLM under the influence of oscillations of special emitters, and the liquid film flowing out of the nozzle output is broken under the influence of the acoustic oscillations of this gas flow, (confer USSR Inventor's Certificate No. 1316713). In the present invention, the source of acoustic oscillations is the GLM gas component and the acoustic oscillations take place in the closed cavity of the nozzle in a self-excitation mode and are superposed on gas/liquid flows in the zone of their collision.

Brief Description of the Drawings

The invention is described in greater detail in the following with reference to the particularly preferred embodiments and accompanying drawings, in which

Fig. 1 is a diagrammatic illustration of the bubble mode of a GLM flow,

Fig. 2 is a diagrammatic illustration of the pseudo emulsion mode,

Fig.3 is a diagrammatic illustration of the portion or plug mode,

Fig.4 is a diagrammatic illustration of the apparatus for carrying out the method according to the invention,

Fig. 5 is an illustration of a first embodiment of the nozzle according to the invention,

Fig. 6 is an illustration of a second embodiment of the nozzle according to the invention, in which the end wall of the resonance cavity is modified,

Fig. 7 is a diagrammatic view of the relation of efficiency of fire-fighting

using the present inventions.

Best Mode for carrying out the Invention

The apparatus in Fig. 4 for carrying out the method according to the invention comprises a tube 2 having an end extending into the liquid in the vessel 1. The other end of the tube is connected to a mixing device or chamber 3 for mixing liquid and gas. Gas is supplied to the mixing device 3 from a gas vessel 4 containing a gas via a tube 20 provided with a valve 7 for regulation of the gas flow to the mixing device 3. Further, the apparatus comprises an outlet tube 5 connected at one end to the mixing device 3 and provided with a nozzle 6 at the other end. Finally, the liquid vessel 1 is connected to the gas vessel 4 by means of a tube 21 provided with a valve 8 for regulating the flow of gas to the liquid vessel.

The apparatus operates in the following manner:

By means of the pressurised gas in the gas vessel 4, fire-extinguishing liquid is dispensed from the vessel 1 and fed along the tube 2 to the mixing device 3, where the liquid is mixed with the gas flowing through the tube 20. The gas/liquid mixture (GLM) flows along the outlet tube 5 and enters the nozzle 6 as a plug flow which is dispensed therefrom. The outflowing flow is subjected to an acoustic field of a frequency corresponding to the frequency of the plug flow, whereby a jet of fine atomised droplets is formed. The nozzle 6 may be formed so as to provide the acoustic field ad described blow.

The nozzle 6 (confer Fig. 5) comprises a cavity of two different sections formed by a large cylindrical portion 16 having a large cylindrical bore 9 and small cylindrical portion 17 having a small cylindrical bore 10. The two portions 16,17 are interconnected by means of an annular wall 19. The small cylindrical portion 17 is closed by means of an end wall 18, thereby forming a small cavity 14. The inner surface 13 of the end wall is plane. Axial outlet holes 11 are formed in the

annular wall 19 and radial outlet holes 12 are formed in the small cylindrical portion 17. The radial outlet holes 12 are formed at such a distance h from the end wall 18 so as to form a resonance chamber 14 therebetween. In said resonance chamber , the energy of the GLM gas component is converted into the energy of acoustic radiation (acoustic energy) acting on the GLM flowing out of the outlet holes as described above.

A thread 15 is formed on the inner surface 9 of the nozzle for fastening the nozzle 6 on the outlet tube 5, and the outer surface of the large portion 16 is of a hexagonal shape.

The holes 11 and 12 are arranged as pairs of holes having intersecting axes, preferably situated in the same radial plane. In the embodiment shown, six evenly distributed pairs of holes are provided circumferentially.

It should be mentioned that the inner surface 13 of the wall 18 may be of another shape than plane. In Fig. 5, the inner surface 13 of the end wall 18 is formed by an end cutter, and in Fig. 6, the inner surface is formed by an ordinary drill, for which reason the end surface is conical. Tests have shown that the function of the nozzle does not depend on the inner shape of the end wall 18, but entirely on the existence of the cavity or resonance chamber 14.

The gas/liquid nozzle of Fig. 5 operates as follows:

The GLM, in this case water mixed with carbonic acid, flows under pressure along the outlet tube 5 to the nozzle and into the cavity of large cylindrical bore 9 as a plug flow. A portion of the plug flow leaves the nozzle through the axial holes 11 as a pulsating jet. At the same time, the small chamber 14 acts as a resonance chamber, whereby a portion of the flow leaves the radial holes 12 as a pulsating jet. As the axes of the outlet holes 11, 12 of each pair of holes are arranged in the same plane, the gas/liquid jets of each pair collide, whereby

refined droplets are formed. At the same time, the acoustic filed formed by the GLM gas component acts on the outflowing jets in the collision zone of the jets causing additional liquid droplets to break.

The standard conditions described in "Methods of Evaluation of fire-fighting ability of fire extinguishers" by O.M. Kurbatsky a.o. were used for testing the method according to the invention employing the nozzle design shown in Fig. 5. A fire centre of a "13 B" type was used as a fire centre comprising a round steel tray with a square of 0.41 m^2 and containing a combustible matter of 13 litres A-76 petrol, confer pages 8-10, in particular.

The tests were carried out on an apparatus constructed according to the principles of the apparatus shown in Fig. 4 and having a liquid vessel contents of 200 l (MIITP-200) and 2 l (OBM-2), respectively. The gas concentration in the GLM was regulated and nozzles with different depths h of the resonance cavity 14 were used (confer Fig. 5).

The efficiency of fire-fighting E can be quantitatively estimated as a ratio of fire centre square S to water mass M used for its extinguishing, e.g. $E=S/M$ (m^2/kg.) The result of the performed tests for MIITP-200 and OBM-2 are given in Table 1 and Table 2 respectively, where the efficiency of fire-fighting E and the time t used for extinguishing are stated depending on the gas concentration r in the GLM and the depth h of the resonance cavity or chamber 14.

The results stated in the tables show that optimum ranges of gas concentration r in the GLM and an optimum depth h exist at which an appreciable increase in E and decrease in t are obtained.

Table 1

Fire-fighting efficiency, m^2/kg; sec					
N	Resonance cavity depth (h), mm	Gas concentration, %			
		0.4	2.0	4.0	5.0
1	3.0	0.12; 9.0	0.20; 5.0	0.25; 5.0	0.28; 4.0
2	5.0	0.11; 10.0	0.22; 5.0	0.24; 5.0	0.25; 5.0
3	8.0	0.11; 11.0	0.40; 3.0	0.38; 3.0	0.36; 3.0
4	10.0	0.10; 11.0	0.25; 5.0	0.28; 4.0	0.28; 4.0

Table 2

Fire-fighting efficiency, m^2/kg; sec					
N	Resonance cavity depth (h), mm	Gas concentration, %			
		0.4	2.0	4.0	5.0
1	1.0	not extin.	0.25; 16.0	0.26; 15.0	0.28; 14.0
2	2.0	not extin.	0.40; 10.0	0.38; 11.0	0.36; 12.0
3	4.0	0.22; 18.0	0.42; 9.0	0.40; 10.0	0.38; 11.0
4	6.0	not extin.	0.26; 15.0	0.26; 15.0	0.25; 16.0

For MIITP-200 the optimum gas concentration range is about 2-35 and the optimum value is h = 8 mm and for OBM-2 the same gas concentration range, but at h values of about 2-3 mm.

The mentioned gas concentrations correspond to a plug flow of the GLM flowing into the nozzle, which was shown by of the vibrations of the outlet tube feeding the GLM to the nozzle. As the diameters of the outlet tube of the MIITP-200 and the OBM-2 differ from one another, the GLM plug flow flowing out is different from one another. The geometrical parameters of the resonance cavities 14

providing resonance oscillations differ correspondingly.

Analogous tests were carried out using an apparatus, OBM-10, having a water contents of 10 l. The results of these tests are presented (confer Fig. 7) by means of curves showing the fire extinguishing efficiency E as a function of the gas concentration r in the GLM, the resonance cavity depth h and the pressure p. It can be seen that in the r range from 0.6 to 2.0 and h = 5 mm an increase in E occurs, which is typical of the resonance phenomenon. This is particularly evident in comparison with the curve plotted for h = 2 mm. In the latter case, such resonance cavity depth does not provide a generation of oscillation resonance in relation to the frequency of GLM plug flow flowing into the nozzle and only a uniform increase in the fire extinguishing efficiency E due to the gas component in the GLM can be seen.

Thus, the tests carried out show the advantages obtained by the present invention in relation to fire-fighting means, and in particular, that a substantial increase (at least 1.5 times) in efficiency may be obtained in comparison with the known means. The efficiency of fire-fighting with a powder fire-extinguisher (OM-10) is shown in Fig. 7 for comparison.

The tests carried out using varying fire-fighting means differing from each other mainly by the diameter of the GLM outlet tube and the GLM pressure show that the plug mode of the GLM flowing out can be provided and that the dimensions of the nozzle resonance cavity can be selected so that the fire extinguishing liquid flowing out breaks into very fine droplets due to the resonance phenomenon. Thus, at additional tests, excellent results have been obtained with flow velocities ranging from 3 m/sec to 10 m/sec in the outlet tube 5 providing a plug flow with a frequency of 25 to 50 kHz.

Claims

1. A method of providing a gas/liquid jet having finely atomised liquid droplets comprising the steps of feeding a mixture of gas and liquid into a tube provided with at least one outlet nozzle having an outlet opening, characterised in that a plug flow is formed (i.e. a flow in which liquid portions and gas portions are separate from each other) in the tube before the flow leaves the nozzle, and subjecting the outflowing plug flow to an acoustic field, being essentially a multiple of the frequency of the plug flow.

2. A method according to claim 1, characterised in that the frequency of the acoustic field essentially corresponds to the frequency of the plug flow.

3. A nozzle to be used in connection with the method of claim 1 or 2 comprising a housing forming a cavity and having an inlet opening and at least two outlet openings (11,12), characterised in that the cavity of the nozzle is formed by two coaxial inner cylindrical faces (9,10) of the housing having differing diameters, an annular face interconnecting the two cylindrical faces (9,10) at one end thereof and being formed on an annular wall (19) of the housing, and a bottom face (13) at an end of the small cylindrical face (10) opposite the annular face, the end of the large cylindrical face (9) opposite the annular face forming the inlet opening of the nozzle, said nozzle further comprising at least one pair of outlet openings, a first outlet opening (11) being formed in the annular wall (19) and a second outlet opening (12) being formed in a portion of the housing forming the small cylindrical face (17), the said outlet openings (11,12) having intersecting axes, a resonance chamber (14) being formed between the bottom face (13) and the opening (12) in the small cylindrical face (17).

4. A nozzle according to claim 3, characterised in that the axes

of each pair of outlet openings (11,12) are arranged in a mutual radial plane through the axes of the cylindrical faces.

5. A nozzle according to claim 3 or 4, characterised in that the axis of the outlet opening (11) in the annular wall (19) extends parallel to the axes of the cylindrical faces (9,10) and the axis of the outlet opening (12) in the portion of the housing forming the small cylindrical face (10) extending radially.

6. A nozzle according to claim one or more of the claims 3-5, characterised in that the nozzle is provided with a plurality of equally spaced pairs of outlet openings (11,12) in the annular wall (19) and in the portion of the housing forming the small cylindrical face (10), respectively.

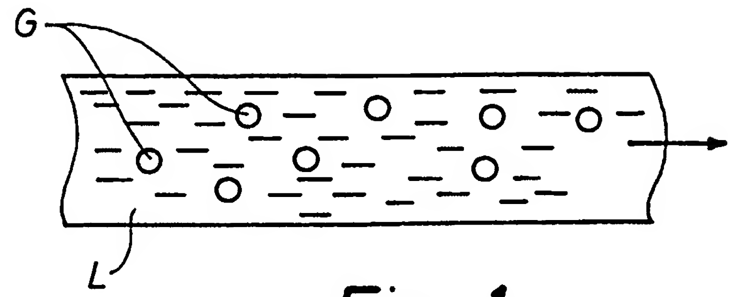


Fig. 1

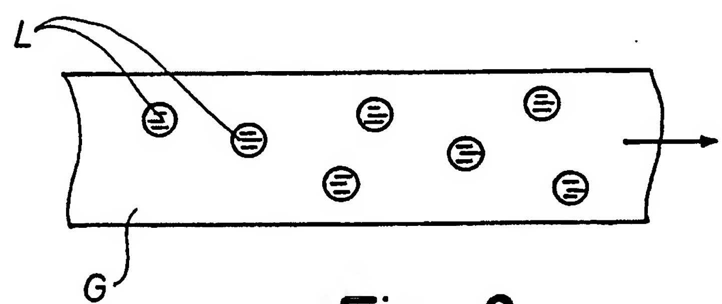


Fig. 2

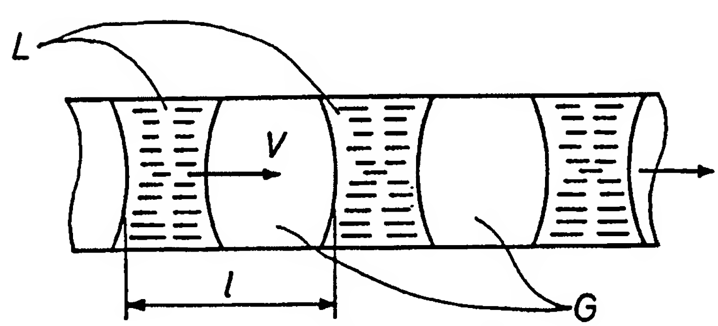


Fig. 3

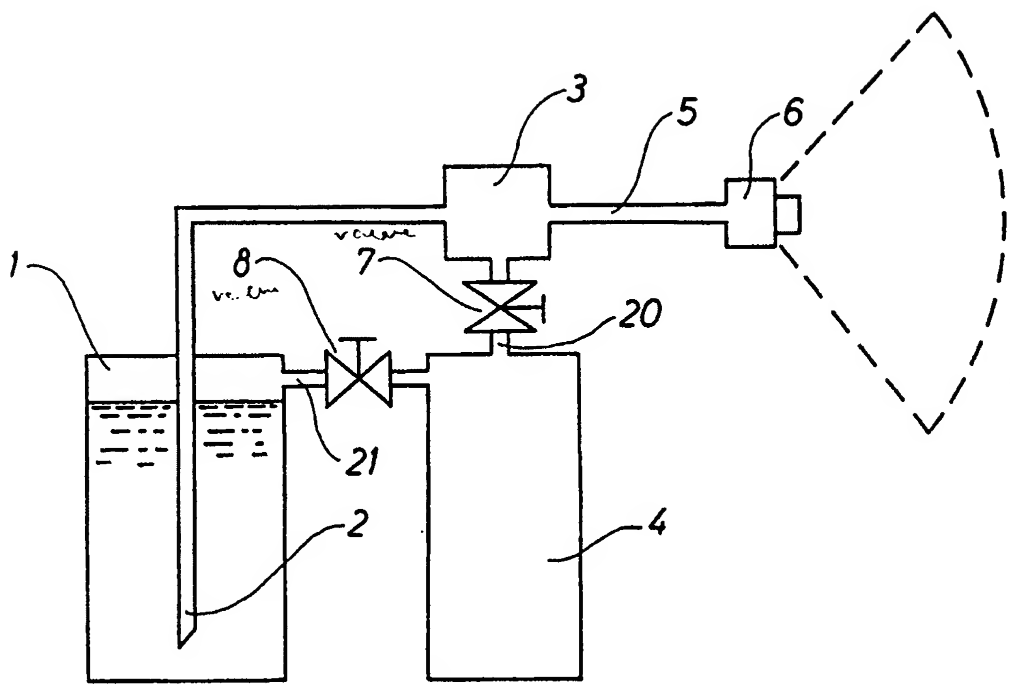


Fig. 4

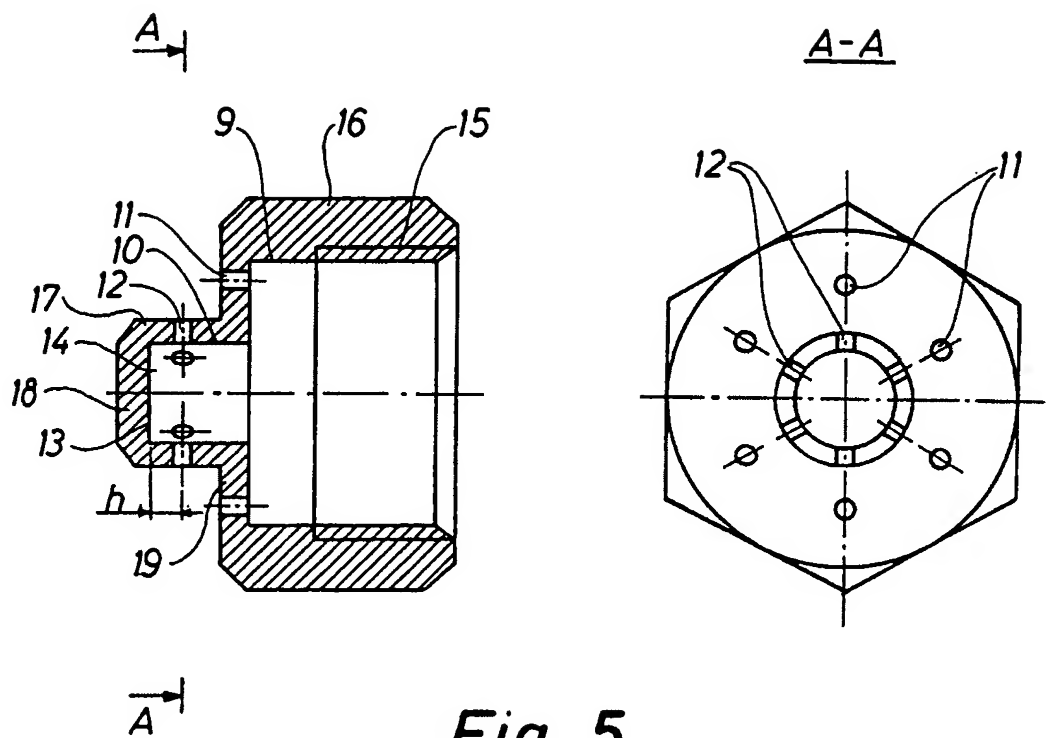


Fig. 5

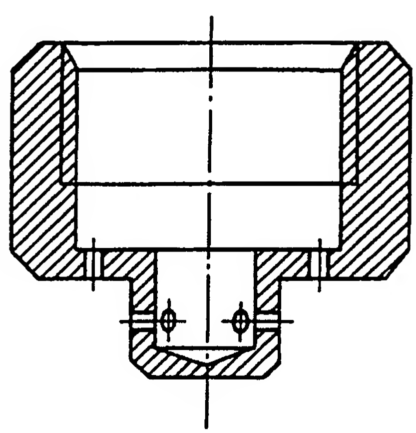
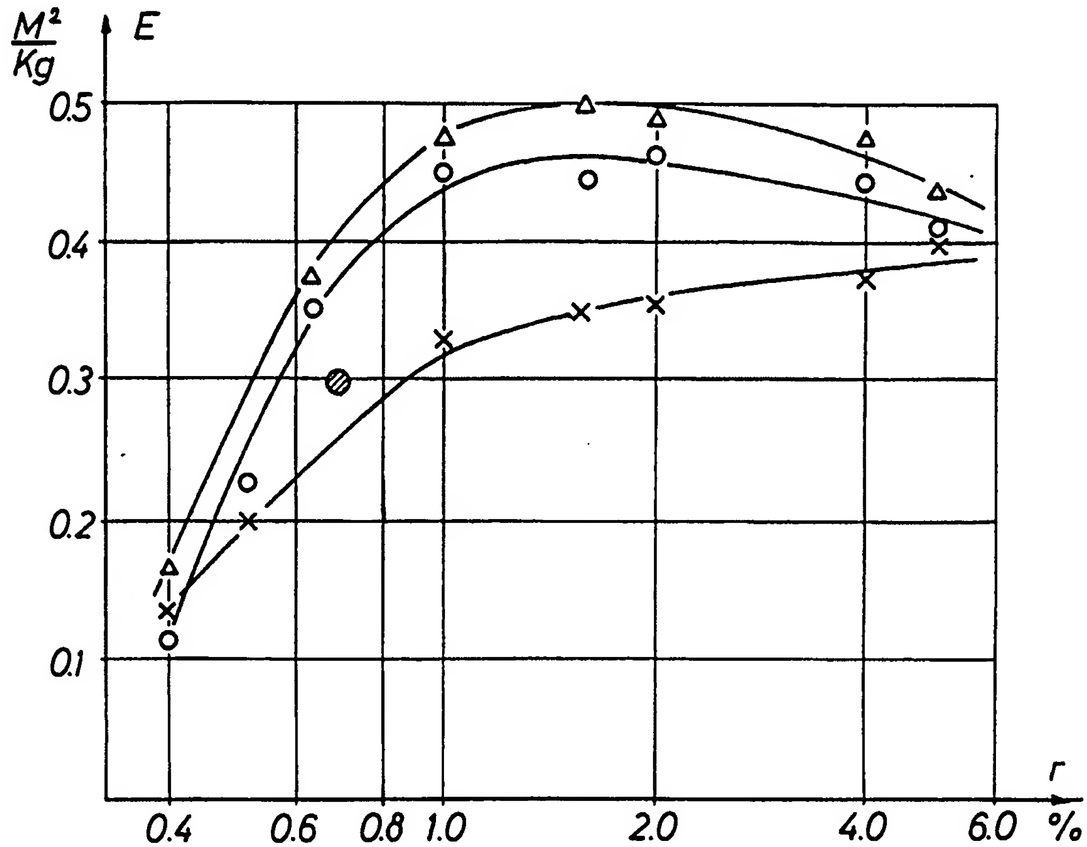


Fig. 6



OBM-10

△ - p = 8 bar, h = 5mm

○ - p = 4 bar, h = 5mm

× - p = 8 bar, h = 2mm

● - OM-10

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 95/00015

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: B05B 17/06, B05B 1/08, B05B 1/26 // A62C 31/02, B05B 1/14
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: B05B, A62C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DIALOG; WPI, CLAIMS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Derwent's abstract, No 86-118167/18, week 8618, ABSTRACT OF SU, 1184567A (LEVSHIN N P), 15 October 1985 (15.10.85) --	1,2
A	Derwent's abstract, No 88- 27281/04, week 8804, ABSTRACT OF SU, 1316713-A (NERASOV E V), 15 June 1987 (15.06.87) --	1,2
A	Derwent's abstract, No 88-166804/24, week 8824, ABSTRACT OF SU, 1353444-A (BOGOMOLOV A A), 23 November 1987 (23.11.87) --	1,2

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
26 June 1995	27 -06- 1995
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INTERNATIONAL SEARCH REPORT

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB-B- 629335	20/05/47	NONE	
GB-B- 629365	04/06/47	NONE	